1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	31 Jan 92	Scientific Paper

4. TITLE AND SUBTITLE
GPS ARMY RESEARCH AND APPLICATIONS

5. FUNDING NUMBERS

(2)

6. AUTHOR(S)
Richard B. Marth, Sr.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Topographic Engineering Center
ATTN: CETEC-LO
Fort Belvoir, VA 22060

8. PERFORMING ORGANIZATION REPORT NUMBER

R-155

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release;
distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The NAVigation Satellite Timing and Ranging (NAVSTAR) Global Positioning System (GPS) is a tool used to support military and civil needs for positioning, navigation and precise timing. The civil needs for positioning, navigation and precise timing. The U.S. Army Topographic Engineering Center (TEC) is studying tactical and civil applications of GPS to Army missions. For the tactial Army, TEC is investigating GPS for use as a precise surveying tool and for accurate use of azimuth. The integration of GPS with an inertial navigation system is also being studied as a potential improvement for tactical navigation and positioning. For the civil missions of the U.S. Army Corps of Engineers (USACE), TEC is investigating the application of Differential GPS (DGPS) to photogrammetry and hydrographic surveying needs. Code-phase DGPS and Carrier-phase DGPS are being studied with the goal of achieving real-time accuracies of 1-3 meters and .1 meter with the respective apporaches.

14. SUBJECT TERMS

Positioning, navigation, precise timing, tactical, civil applications

15. NUMBER OF PAGES
6

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	

GPS ARMY RESEARCH AND APPLICATIONS

Richard B. Marth, Sr.
U.S. Army Topographic Engineering Center (TEC)
Topographic Developments Laboratory
Surveying Division
Tactical Positioning Branch
Fort Belvoir, Virginia 22060-5546

ABSTRACT

The NAVigation Satellite Timing and Ranging (NAVSTAR) Global Positioning System (GPS) is a tool used to support military and civil needs for positioning, navigation and precise timing. The U.S. Army Topographic Engineering Center (TEC) is studying tactical and civil applications of GPS to Army missions. For the tactical Army, TEC is investigating GPS for use as a precise surveying tool and for accurate determination of azimuth. The integration of GPS with an inertial navigation system is also being studied as a potential improvement for tactical navigation and positioning. For the civil missions of the U.S. Army Corps of Engineers (USACE), TEC is investigating the application of Differential GPS (DGPS) to photogrammetry and hydrographic surveying needs. Code-phase DGPS and Carrier-phase DGPS are being studied with the goal of achieving real-time accuracies of 1-3 meters and .1 meter with the respective approaches.

INTRODUCTION

Information about elements of a task contribute to the management of the total task. The location and status of personnel, material, resource and other physical items are two information elements which play a role in project management or the development of a management strategy. The U.S. Army Corps of Engineers (USACE) management responsibilities or contributions of information to project management can be generalized into two arenas, military and civil. Position information is a part of the USACE military mission to establish high order survey control for the management of the battlefield. For the USACE civil missions, position information is vital to the management and protection of wetlands, the Nations waterways and other civil projects which the USACE has responsibility. The NAVigation Satellite Timing and Ranging (NAVSTAR) Global Positioning System (GPS) is a new positioning tool which offers the USACE highly accurate positioning and more rapid position determination capabilities. The U.S. Army Topographic Engineering Center (TEC) is conducting research in GPS applications to the USACE military and civil missions. TEC is also investigating GPS application to positioning and orientation requirements for other Army users.

Global Positioning System (GPS)

The Global Positioning System (GPS) is a DoD satellite based system managed by the Air Force. When GPS is fully operational, there will be 24 satellites (21 operational, 3 spares) in the constellation. The constellation configuration will provide 3 dimensional positioning 24-hours a day. The satellites broadcast on two wavelengths, L1 and L2, 19 cm and 24.4 cm respectively. L2 use has been primarily for Ionospheric refraction correction. The system information can be degraded to protect the high positional accuracies from immediate enemy use. Thus the positioning accuracies achievable with GPS will depend on the capability of the user's GPS receiver. Standard Positioning Service (degraded satellite information) will be available to everyone and has a horizontal positioning accuracy of 100 meters. Precise Positioning Service (PPS) will be available to authorized users and has 17-meter horizontal positioning accuracy. Current Government policy calls for implementation of the capability to degrade satellite information.

GPS will meet the stated position accuracy requirements for most of the Army. For some military users, geodetic quality positions are needed. The topographic surveyor with responsibility for establishing geodetic quality survey control and positioning some weapon systems are among those who need higher order positioning accuracy. The USACE civil missions such as wetlands protection and dredging management and channel maintenance require geodetic quality positioning of systems used to support these missions. The higher positioning accuracy will be achieved using GPS absolute positioning techniques and Differential GPS (DGPS) techniques. DGPS techniques can be divided into two groups, carrier tracking and code tracking.

Absolute Positioning

Absolute positioning is a single GPS receiver operation. Meter or less positioning accuracies have been achieved using long station occupation times and post-processing of the GPS data. Station occupation times of 4 hours have been recommended as part of the process. The long occupation times give better time averaging of multipath, Ionospheric effects and other effects on the broadcast signal. With PPS, 3- to 5-meter accuracy has been achieved with 4-hour observation times and with 10 minutes of post-processing using the broadcast ephemeris. This accuracy is improved to a meter or less by post-processing with the precise satellite ephemeris. The use of dual frequency GPS receivers can also be beneficial for absolute positioning.

Carrier Tracking DGPS

Geodetic quality control can be established using the DGPS carrier tracking technique. This technique is being used to

achieve decimeter level positioning accuracies. The carrier tracking technique currently requires static operation and can be used real-time or by post-processing the data. Two or more GPS receivers are used for this technique. One receiver is placed on a known survey control point (SCP) and the remote receivers are placed at locations where SCPs are needed. The carrier phase is observed for each satellite being received at the known SCP and the remote SCP. Once cycle ambiguities are resolved, the vector between each ground station can be precisely determined. This then permits the position of the unknown position to be computed to very high accuracy. For post processing, time tagged information is recorded by all receivers used in the survey and the information is post-processed.

Code Tracking DGPS

For surveys which do not require geodetic quality control, control can also be established using the DGPS code tracking techniques. These techniques have been used to achieve 3-meter positioning accuracies. The code tracking techniques can be applied real-time or used in post-processing. Two or more GPS receivers are used for these techniques. One receiver is placed on a known SCP and the remote receivers are placed at locations where SCPs are needed. Time tagged information is recorded by all receivers used in the survey. At the known position, the difference between the known position and the GPS determined position is used to determine either coordinate corrections or the pseudo range corrections to each satellite. Either coordinate corrections or pseudo range corrections are then applied to the information recorded at the remote receivers. If a communications link is available, the corrections can be determined in near-real-time as the survey is being conducted and transmitted to the remote receivers. The remote receivers can be static or moving.

APPLICATIONS/RESEARCH

STATIC GEODETIC SURVEYING

Static geodetic surveying is being performed using both differential and absolute techniques. The concept of differential GPS surveying already has been adopted in the surveying community to perform geodetic surveys. This concept is so accepted that the National Geodetic Survey no longer uses conventional methods and has completely converted to GPS for horizontal control. Since GPS measures heights relative to the spheroid and not the geoid, other factors must be considered when using GPS for vertical control. This technology has been demonstrated to a majority of USACE Commands, the Army Engineer Battalions (Topographic) (EBT) and the 1st and 3rd Armored Division artillery surveyors during REFORGER '90. TEC has subsequently trained

USACE surveyors and EBT surveyors in surveying with GPS. USACE and the EBTs presently own about 47 receivers for horizontal control with more on order. TEC has developed an automated deformation monitoring system using this technology, yielding accuracies of a few millimeters. This system was demonstrated at Dworshak Dam in northern Idaho during FY89.

The absolute mode for static geodetic surveying is being used by the Defense Mapping Agency (DMA) and others to establish control. TEC recently converted DMA mainframe software to operate on a portable PC that computes positions to within 1-5 meters. This was used by the 30th Engineer Battalion in Operation Desert Storm. This technique is well beyond the capability of standard GPS products, and requires a combination of Precise (P) code, the Course Acquisition (C/A) code, the carrier signal and 4 hours of static data collection. TEC has developed specifications for a GPS receiver which will meet the requirements for absolute geodetic surveying.

DYNAMIC SURVEYING

USACE will soon be positioning hydrographic survey boats and dredges in a dynamic mode using GPS. Though it will have many uses, if just survey vessels use this technique, USACE could save an estimated $10 million annually. Research in applications of dynamic surveying to the battlefield environment is also being conducted at TEC. Two levels of accuracy are being investigated for dynamic surveying, meter accuracy (Code Tracking DGPS) and decimeter accuracy (Carrier Tracking DGPS).

The meter-level code tracking mode would meet the general requirement for positioning boats or vehicles in peacetime or time of conflict. With cooperation between several Federal agencies (National Oceanographic and Atmospheric Administration, Coast Guard and USACE) it would be possible to establish a nationwide network of reference stations for all maritime navigation. Even without the nationwide network, such a system could easily be set up on a regional basis. The Wilmington District already has begun to establish a district-wide network to position survey boats to better than 3 meters in a real-time dynamic differential mode. This technique also was demonstrated during REFORGER '90 to the artillery surveyors.

With additional research and development, it will be possible to position a moving platform within 10 centimeters in three dimensions using carrier tracking techniques. This is being pursued aggressively for dredging and hydrographic surveying under the USACE Dredging Research Program. A prototype decimeter-level, real-time, positioning system is under development with a target availability date of September 1993. In addition to vessel positioning, this system will be used to measure offshore tides with phenomenal precision. The benefits to the

marine community include safer navigation and increased commerce based on precise, real-time positioning. This increased accuracy will improve USACE quantity surveys for dredge payments, thus avoiding overpayment and eliminating claims based on differences between USACE and contractor survey.

AZIMUTH DETERMINATION

TEC has been investigating the application of GPS for azimuth determination. Currently, two approaches are being studied. One involves determining two GPS positions with a single receiver on a line pointing in the direction of unknown azimuth, while the other applies interferometric principles to the received signals. The two-position azimuth determination study is being conducted as an Independent Laboratory In-house Research (ILIR) initiative. Algorithms are being developed for a single GPS receiver to be used to determine azimuth. Early results indicate that an azimuth accuracy of 1 mil (6400 mils = 360 degrees) on a 22 meter baseline is possible.

The interferometric technique for azimuth determination is being conducted under the sponsorship of the Army Space Technology Research Office (ASTRO). Three brassboard Azimuth Determining Systems (ADS) were developed, and each ADS used a different approach to solving the phase ambiguities. The three ADS were successfully demonstrated at the U.S. Army Field Artillery School, Fort Sill, Okla., in September 1990. An azimuth accuracy of 5-8 mils was demonstrated. The next step of ADS development will be a Proof-of-Principle demonstration with ADS on two weapon systems. An azimuth accuracy of 1 mil will be required. Positioning performance of the ADS is required to be the same as PPS GPS receiver.

Inertial Navigator/GPS Hybrid

The integration of GPS and an inertial navigation system (INS) offers the benefits of increased autonomy, redundancy and potentially will improve navigation performance. TEC is providing technical support to the Product Manager for M109A6 Self-Propelled Howitzer (Paladin) for the development of a Modular Azimuth Positioning Systems (MAPS)/ GPS Hybrid. The MAPS is the INS which is currently being installed as part of the Paladin fire control system. The MAPS/GPS hybrid will reduce the reliance of Paladin on survey control support and offer a degree of redundancy for navigation. The MAPS/GPS Hybrid development includes provisions for DGPS operation in order to meet the higher positioning requirements. Systems such as FIREFINDER, the Positioning and Azimuth Determining System (PADS) replacement, and future navigation systems for weapon systems will require more accurate horizontal and vertical information.

Aerial Photogrammetry

DGPS has the potential to be a valuable tool for aerial photogrammetry. The position of a DGPS equipped aircraft can be accurately determined during the photographic mission. With the aircraft position known and overlapping flight lines, all of the parameters required to complete the analytical model can be computed. This results in ground control points only being needed for quality control. TEC supported a Seattle District program to use DGPS for aerial photogrammtry with moderate success. TEC is currently completing arrangements for a cooperative government - industry investigation and development of an economic and user-friendly DGPS aerial photogrammetry system.

OTHER DYNAMIC USES

Many organizations involved in Geographic Information Systems (GIS) data base creation, such as outlining wetlands, are extremely interested in obtaining training quickly. With careful implementation it is feasible that GPS can provide an accurate, inexpensive and rugged survey tool for the non-surveyor. These groups also would need the differential capability and could easily use the reference sta
tions established by the surveyors. Other institutions are interested in GPS positioning for construction automation.

CONCLUSION

Near-real-time application of GPS appears promising for adaptation to military and civil surveying tasks. Questions need to be resolved for the Army surveyor and Army DGPS users. Among these are the availability of a radio link for corrections, the classification of the broadcast corrections and the maximum separation distance between known and remote receivers. These questions are being addressed by the GPS policy makers and are being researched by TEC.

Although not fully operational, GPS already has become an invaluable tool for the USACE as the Corps supports growing national missions. Presently, surveying using GPS is an integral part of the Corps development of the nation's water resources. Topographic surveyors are using GPS to perform peacetime missions and have supported tactical operations during Operation Desert Shield/Storm. GPS has become and continues to be a multifaceted tool of the Corps.